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TRAINING EFFECTIVENESS [illegible] OF NAVAL TRAINING DEVICES PART 1: A STUDY OF SUBMARINE DIVING TRAINER EFFECTIVENESS

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13. ABSTRACT

A study of the effectiveness of ~~the~~ SS(N)613 (Device 21B20/A) and SSB(N)627 (SP device) submarine diving trainers in developing Diving Officer basic skills during a five-week Submarine Officers Indoctrination Course was conducted at the U.S. Navy Submarine School in New London. A standard 15-minute exercise to serve as a standard performance measure was administered at the beginning of each of seven two-hour training sessions. The exercise consisted of two tasks requiring maintaining ordered depth during conditions of speed changes, two tasks requiring changing to a new ordered depth, and one task requiring maintaining ordered depth during buoyancy change. Performance of 16 student crews was compared with performance of five experienced crews. Results indicated improvements in student performance on the first four of the above tasks which approached 90% of experienced crew capabilities by the seventh training session but performance of the "buoyancy change" task was less than 50% of experienced crew capability by the seventh session. Evidence was presented indicating negative transfer effects resulting from interpolation of one training session on the SS(N) 594 (Device 21B56/A or B) training device. The report discusses some of the problems involved in evaluating training devices within a school setting and suggests techniques for adjusting experimental methodology to overcome study design constraints.

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FOREWORD

The Naval Training Device Center is engaged in a program of in-house and contractual studies designed to evaluate the effectiveness of training devices. This report describes Part 1 of such a study. It reports on the evaluation of the Advanced Control Trainer (Device 21B20/A) for training Flasher SSN 613 class submarine crews, and a special purpose trainer simulating the control stations of the SSBN 627 class submarine. As a result of a temporary breakdown of Device 21B20/A, the evaluation also involved a cursory survey of Device 21B56/A, Submarine Control Trainer for the SSN 594 class submarine. This device, although not intended for this purpose, was routinely used as a substitute trainer for the 21B20/A.

Part 2 of the study reports on the evaluation of Device 2F66A, S2E Aircraft Weapon System Trainer. The results of Part 2 are described in a separate report (NAVTRADEVCEN 69-C-0322-2).

These studies have several objectives:

a. To apply some of the evaluation techniques derived from previous studies on methodology to the practical evaluation of training as it is performed on the training device in the field.

b. By evaluating training across different classes of devices, it is expected that certain patterns will be identified which will provide an empirical basis upon which to build more practical and reliable techniques for evaluation.

c. To obtain quantitative data derived from objective measurement techniques with which to support or reject any subjective feelings about the training capability of the devices.

d. To provide evaluative information on particular major training devices. The large number of devices currently in use precludes their evaluation by specialists in the field of training effectiveness evaluations. In view of this, an ultimate goal is to provide information, derived from these studies, which can be used to improve trainer design, and to aid the training device user in assessing the effectiveness of specific trainers, both in terms of their design and their methods of utilization.

A particularly useful finding of this submarine trainer study is, that although no negative transfer effects were observed from alternating sessions on the SSN 613 and SSBN 627 class trainers, the SSN 594 trainer resulted in negative transfer when used as a substitute for the SSN 613 trainer.

This should not be interpreted as a condemnation of Device 21B56/A in training SSN 594 class submarine crews for which it was designed, but rather to reject it as a substitute trainer for SSN 613 and SSBN 627 class submarine crews.

Another noteworthy example of the usefulness of this type of evaluation is illustrated by the graphical presentation of student progress over the allotted number of training sessions. It is clearly indicated that although student team performance during speed and depth changes reaches 90 per cent of that of the experienced crews, performance of the task which involved buoyancy change is only at the 50 per cent level by the end of the training sessions. Prediction of proper course length may be estimated by such means. (See Figure 8 on page 22.)

It is with this purpose in mind, i. e., to clarify the effects of training in order to more intelligently control the training situation, that these and future studies are dedicated.

Joseph A. Puig

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Project Psychologist
Human Factors Laboratory

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION I

INTRODUCTION

The vast majority of training programs, whether military, industrial or business, are conducted without benefit of systematic evaluation of their effectiveness. In most instances, this does not become a critically important consideration. Deficiencies in a formal training program can often be remedied by subsequent on the job training (OJT). However, when the training program involves use of extremely costly training devices, as is the case for many military systems, an assessment of the effectiveness of such devices becomes a matter of considerable practical importance.

This study is one in a series of studies being conducted for the Naval Training Device Center to evaluate trainer effectiveness. Preferably, the methods employed will be sufficiently similar across families of trainers so that comparisons may be made concerning relative costs and effectiveness. Within a family of trainers, the methods should provide for the relation of specific trainer characteristics to particular training results.

It is anticipated that at the local school level such studies can guide instructional personnel in better use of their equipment.

On a larger scale, such studies can influence the design of devices in terms of incorporating or eliminating costly features which affect a device's operating characteristics or its utility in a school setting. Among such considerations are, for example, whether motion cues are essential in learning to use certain devices; or whether a training device should be designed for full crew, team, or individual operator use.

SECTION II

PURPOSE OF STUDY

The primary objective of the Training Effectiveness Evaluation Study was the measurement of training obtained by the Advanced Submerged Control Trainer, Device 21B20/A for the SS(N)613 class attack submarine.

It had been desired to evaluate all design capabilities of the Device 21B20/A. However, it was not feasible to establish sufficient experimental control to assess casualty training capabilities. Consequently, the study was limited to assessment of the device in terms of training in rudimentary ship control.

The nature of the training course, involving the above trainer and a special purpose device simulating the ship control stations of the SSB(N)627 class submarine, resulted in a broadening of the study goals to include evaluation of this latter device.

SECTION III

METHOD

A. INTRODUCTION

An established technique for measuring training effectiveness is to compare the performance of two groups engaged in some operational task, one group having been exposed to prior training on related tasks and one group serving as a control. If the trained group's performance is markedly better than the control group's performance the increment may be attributable to the training received. Although this is an oversimplification of the basic method, the description is sufficiently accurate to introduce the point that this technique may not be entirely appropriate in evaluating specific training devices in use in military schools.

If rigorous control can be obtained over the training environment and, at least for a period of time, over the operational environment then it is reasonable to expect that clear relationships can be found between training and operational performance. If, however, the training device evaluations must take place within a normal training context, innumerable uncontrolled variables will operate to mask any relationships that may exist. These uncontrolled variables concern aspects of the training devices, the students, the syllabus of instruction and local school practices. An awareness of their potential effects is essential not only to the design of a study which will assess training device effectiveness but also to an interpretation of the results of such a study.

B. STUDY VARIABLES

1. THE TRAINING DEVICES

The advanced Submerged Control Trainer Device 21B20/A (representing the SS(N)613 class of submarine) was manufactured by the General Dynamics Corporation, Electric Boat Division, for the U.S. Naval Training Device Center and was modified and redesigned by Hydrosystems, Inc., Farmingdale, N.Y. Device 21B20/A actually consists of two submarine diving trainers: SS(N)613 class and SS564 class. (The SS564 class trainer was not used in this study and therefore will not be described.) The purpose of the device is to provide highly realistic training in submarine control under normal and emergency conditions, particularly in providing decision-making training in major emergencies which cannot safely be realistically simulated at sea.

Device 21B20/A is located at the U.S.N. Submarine Base, New London, Connecticut. It is housed in a two-story building approximately 67-1/2 feet long, 36 feet high (including a cooling tower located on the roof), and 48 feet deep. The SS(N)613 class trainer is a semi-enclosed platform containing simulated steering and diving controls and instruments, and ballast controls and instruments closely approximating in layout and function the ship's control station. Other major components of the trainer include an instructor console, a digital computer and peripheral equipment, hydraulic equipment, and an auxiliary maintenance shop. In general, the trainer is designed to provide training in

steering, diving, ballast control, and a variety of emergency procedures (see Appendix C).

The trainer provides a realistic training environment duplicating crew station, layout, appearance, and operation of controls and instruments of the SS(N)613 class submarine. The trainer simulates all important ship control systems, which respond dynamically in the manner of actual submarines. This is accomplished by the simulation of the internal submarine environment and the environment external to the ship. The internal environment reproduces the ship control station of the submarine by furnishing and activating all equipment that indicates movement of the submerged submarine. The external environment consists of surface effects, near surface effects, wave action (sea state), and bathythermal effects. The establishment of a specific problem environment (including initial conditions, control, and monitor) is accomplished by the instructor at the control console. The console may also be used to insert malfunctions and casualties. The major components of the trainer, with applicable controls and indicators, are described individually, below.

Platform. The platform, supporting structures, and hydraulic drive mechanism are installed in a 19' x 18' room. The semi-enclosed platform is gimbal-mounted to provide motion in pitch angle through a range of ± 45 degrees, and roll angle through a range of ± 30 degrees. (Pitch and roll angles, however, are computed through a range of ± 60 degrees and the computations are fed back to the appropriate panel displays). Mounted on the platform are the steering and diving stations and the ballast control station which are identical in configuration and relative location to the operational stations aboard the SS(N)613 submarine. The controls and instruments associated with these stations simulate the performance, including dynamic responses, of the operational equipment. The platform is partially covered by a lightweight sheet metal cowl which extends around 2-1/2 sides of the platform and partially blocks out external distractions. A safety interlock inhibits platform motion when the entrance gate to the platform is open.

Steering and Diving Station. The steering and diving station is a two-position ship control station with the outboard primary position located to the left of the inboard position. An emergency helm position is also provided. The ship controls are designed to duplicate the operational controls, including the emergency helm, in characteristic forces, feel, physical form, and manual movement. Two adjustable seats located at the control station are similar to the seats installed in the submarine. Total travel of the control wheels is 122-1/2 degrees each side of centerline to provide for a rudder travel of 35 degrees each side of center. Pedestal motion at the primary stations is 15 degrees fore and aft of the neutral position, producing movement of ± 20 degrees on the fairwater planes and ± 25 degrees on the stern planes. Operating forces for the primary controls approximate those on the SS(N)613 submarine. The emergency helm is mounted to starboard of the planes ~~control stations. The emergency helm has a rotation of ± 22-1/2 degrees.~~ The steering and diving panel, located at the forward end of the platform is 109 inches wide and 82 inches high. The indicators and controls used by the helmsmen and planesmen are configured on this panel in the same manner as those on the submarine.

Ballast Control Panel. The ballast control panel (BCP), mounted on the port side of the platform is 70 inches wide, 62 inches high, and 16 inches deep. The BCP controls such functions as operating controls for vent and blow of main ballast tanks, trim system, and other trim and list controls, all of which are directly under the control of the panel operator. The BCP simulates exactly the operational equipment of the SS(N)613 submarine.

Instructor's Console. The instructor's console is installed on the mezzanine adjacent to the simulator platform, and is 60 inches wide, 36 inches deep, and 48 inches high. The controls and indicators on the console are used to establish initial conditions, monitor operations, insert malfunctions, or casualties, and stop and start the platform drive system or the computer system.

Digital Computer. The digital computer operates in real time in order to maintain a realistic training situation. It handles all computations and Boolean logic processing necessary to simulate the submarine systems and external environment, including sea state and dynamics. The resolved equations produce output signals which are fed back to the simulator, where they affect instrument indications, control capabilities, and platform attitudes to approximate submarine characteristics as a normal part of the training operation.

The SS(N)613 trainer was used in conjunction with the SSB(N)627 diving trainer at New London for the group of students selected to serve as subjects in the present study. This trainer is similar in structure to the SS(N)613 except that the instructor's console is located directly on the training platform for the SSB(N)627. Sound and motion capabilities are similar for the two trainers although the SSB(N)627 trainer is driven by an analog computer.

Although both trainers accurately simulate their respective class submarines, they do not have the same operating characteristics or responses to given input and control conditions relative to each other (e.g., the SS(N) 613 class, being shorter and lighter than the SSB(N)627, is more responsive to control movements).

During conduct of the study it was necessary to shutdown the SS(N)613 trainer for three days for repairs. The SS(N)594 simulator (Device 21B56A) was used as a substitute trainer during this period. The SS(N)594 is in the same class (Permit) as the SS(N)613, although approximately 20 feet shorter. Therefore, it is hydrodynamically different. The SS(N)594 trainer is not as "sophisticated" as the SS(N)613 trainer and does not duplicate the action of the ship as accurately. For example, the SS(N)594 trainer does not consider bathythermal effects at different depths.

2. STUDENTS

The training devices are used in three major ways: maintaining established skills (refresher training), providing training in coping with hazardous situations (casualty training), and indoctrination training. These types of training are administered differentially to submarine-qualified crews and to students receiving initial instruction in submarines.

Refresher training is oriented toward fully qualified and experienced submarine personnel. It is chiefly concerned with maintaining established

skills and providing additional practice on maneuvers which may be infrequently practiced in the operational setting. For SSB(N)627 class submarines, this type of training is particularly appropriate since crews alternate on extended patrol assignments. Crews based on shore for many months can thus maintain their skills at acceptably high levels. These crews were not judged to be appropriate subjects for the present study for a variety of reasons. Sample size would be relatively small, availability for scheduled trainer sessions was doubtful, the content of the practice sessions was determined by individual ship's officers, and the high skill levels of submarine-qualified personnel appeared to preclude the obtaining of meaningful measures of learning. Moreover, there appeared to be no opportunity to obtain comparable performance measures in the operational environment.

Casualty training provides the opportunity to practice responses to ship control situations which would be unnecessarily hazardous to simulate in the operational setting. By its very nature, in requiring rapid and precise actions to complex stimuli, this type of training is beneficial only to crews who have already mastered routine operations. Casualty training is given to experienced crews to maintain skill levels. Although casualty training would appear to offer an opportunity to assess vitally important characteristics of the diving trainers it proved to be unacceptable. The submarine-qualified crews who receive this training are assigned to the school for one week. The exercises they practice are selected by the individual ship's officers and would not be under experimenter control. If errors occurred the practice would stop, the error would be discussed, and the trial would recommence. Testing could be accomplished only on the final day, precluding the obtaining of learning curves, and there would be no opportunity to obtain corresponding performance measures at sea because of the hazards involved in simulating the casualties.

Indoctrination training, in general, seeks to establish basic skills which can transfer to the operational setting and provide a basic additional skill development. There are two indoctrination courses at the Submarine School. The Basic Submarine Officer's course is an extensive 24-week program to train selected officers in submarines. The course covers electricity, engineering, tactics, weapons, communications, commissary, and supply. The second, (which provided the present study sample) is the Submarine Officer's Indoctrination Course (SOIC). This is an intensified five-week experimental program to train selected, newly-commissioned officers in submarine safety, diving officer duties, and division officer duties.

The diving trainer portion of the SOIC program is specifically geared toward familiarizing the student with duty requirements for each crew station of the diving team, familiarization with standard phraseology and routine procedures, and familiarization with rrective actions for certain malfunctions. Training is accomplished in five classroom hours and seven two-hour sessions in the diving trainers. Twelve of the 14 training hours in the two simulators are spent on submerged control; six hours are spent on trim analysis and trimming before the students are exposed to special evolutions. During the final two hours the students observe demonstrations on casualty control. (Appendices A and B list the training objectives for each classroom and trainer session).

Eighty-nine students from the fall, 1969, SOIC class served as subjects in this study. The students were divided by the school into 16 groups varying from five to six students per group.

3. THE TRAINING PROGRAM

There are several aspects of the training practices at the Submarine School which bear upon the general issue of training device evaluation which is conducted <u>in situ</u>. The primary mission of the school is, of course, to instruct. Consequently, research studies must necessarily accommodate to the school schedules and training practices. These are not always optimum for research control.

First, few of the SOIC students were submarine-qualified. The indoctrination syllabus was established to progress from extremely simple actions in the trainer to exercises which required a modicum of finesse. The brief five-week training period did not permit exposing the students to the full range of capabilities which had been designed into the trainers, nor did it permit the students to attain appreciable competence in performing even moderately difficult exercises. The stated objective of the syllabus was that the training serve as an introduction to crew stations in the diving team and train the students to perform the duties of diving officers. The significance of this for the present study concerned the performance measures to be selected. During each training session new skills were introduced and practiced. Unless common performance features could be abstracted and measured from each session it would be difficult to demonstrate improvements in performance. Alternatively, if it would be possible to test the students on a standard exercise at, say the beginning of each trainer session it might be possible to measure improved performance. But the standard exercise would have to be (a) so simple that the students could be expected to achieve some measure of success on their first trial yet (b) sufficiently difficult that they would not achieve perfect success prior to their final trial. The selected exercise would, of course, have to be a relevant job sample within the context of the total task. (Tasks satisfying these provisions are described in section D, below).

During the five-week duration of the course, the students received 14 hours of trainer instruction. These hours were approximately equally divided between the SS(N)613 and SSB(N)627 trainers, a condition which precluded the attributing of performance changes to particular design characteristics of the SS(N) 613 training device.

The crew stations on the trainers consisted of the sternplane operator (SP), the fairwater plane operator (FWP), the ballast control panel operator (BCP) and the Diving Officer (DO). The instructor assumed the role of Officer of the Deck (OOD). The student groups consisted of five or six men. Consequently, one or two of the students observed the training from the mezzanine for a period of time, after which the group members rotated among the crew stations. In this manner, each student received some experience at each crew station in consonance with the school objective of familiarizing the students with the various positions. It is relevant to note that changing crew composition, shifting among crew stations, and alternating between trainers somewhat complicates the business of obtaining meaningful performance measures. Also, obtaining comparable measures of these students in the operational environment is precluded since none of the officers would normally man any of the ship control stations other than that of Diving Officer.

C. CRITERION SELECTION

Both trainers provided the capability of measuring a variety of subsystem and system status indicators, many of which directly concerned individual crew members' skills at particular control stations. These are indicated in Figure 1, which illustrates the sequence of gross events for a submarine diving team which are relevant to criterion selection. During normal operation, the planesmen monitor their status indicators and take corrective action to maintain the ship on ordered depth or heading. For other than maintaining steady state conditions, the DO becomes aware of a discrepancy between present and desired system states. This awareness may come from a command by the OOD to change depth, heading or speed, or it may come from a crew member's report of a casualty within the ship ("flooding in the engine room") or it may come from his monitoring control position displays or ship status displays. The DO then orders corrective actions to be made by SP, FWP, and/or BCP operators. Their control positions are displayed (subsystem status indicators) on their instrument panels. The changes in control positions cause changes in the submarine's trim, buoyancy, speed, heading, hull angle, roll angle, or depth, and these changes are also displayed (system status indicators) on the instrument panels. The instruments provide feedback to the DO concerning effectiveness of the actions and he continues to order changes until the desired system state is attained.

The selection of practical and relevant measurement points within this cycle is dependent upon several considerations: student rotation among crew stations, beginning student capabilities, local school practices, and submarine hydrodynamics. Student rotation among crew stations (and between trainers) suggested that it would be extremely difficult to control practice times for individuals at each station in order to measure performance as a function of training time. The limited capabilities of the students during initial training sessions suggested that performance in coping with hazards and casualties or in accomplishing difficult evolutions or trimming problems should be ruled out. Local practice of using a constant heading eliminated rudder control as a performance measure. And submarine hydrodynamics resolved the remaining issues. A submarine's engine, ballast, and planes controls determine the ship's location in the water, and its attitude. These system states are interacting. The submarine's speed, weight* and hull angle combine to affect its depth. Consideration of an individual measure of any one of the three can be misleading (i.e., a negatively buoyant ship may sink despite a positive, or "up", pitch angle, but the sinking could be offset by increasing the speed). Therefore, the depth of the submarine is the resultant of team interactions, including the timeliness and correctness of commands to individual team members, taking into consideration the tactical conditions(environment) existing at the time.

In the present study, therefore, the measure of performance selected was depth, in accord with the importance of depth control in operational settings. The task to be assigned the crews was to reach and maintain ordered depth and their success in doing this was to be periodically recorded. Variability in team composition and crew stations was ignored; the depth measure was regarded as a team output and transient fluctuations in team configuration were, consequently, unimportant for present measurement purposes.

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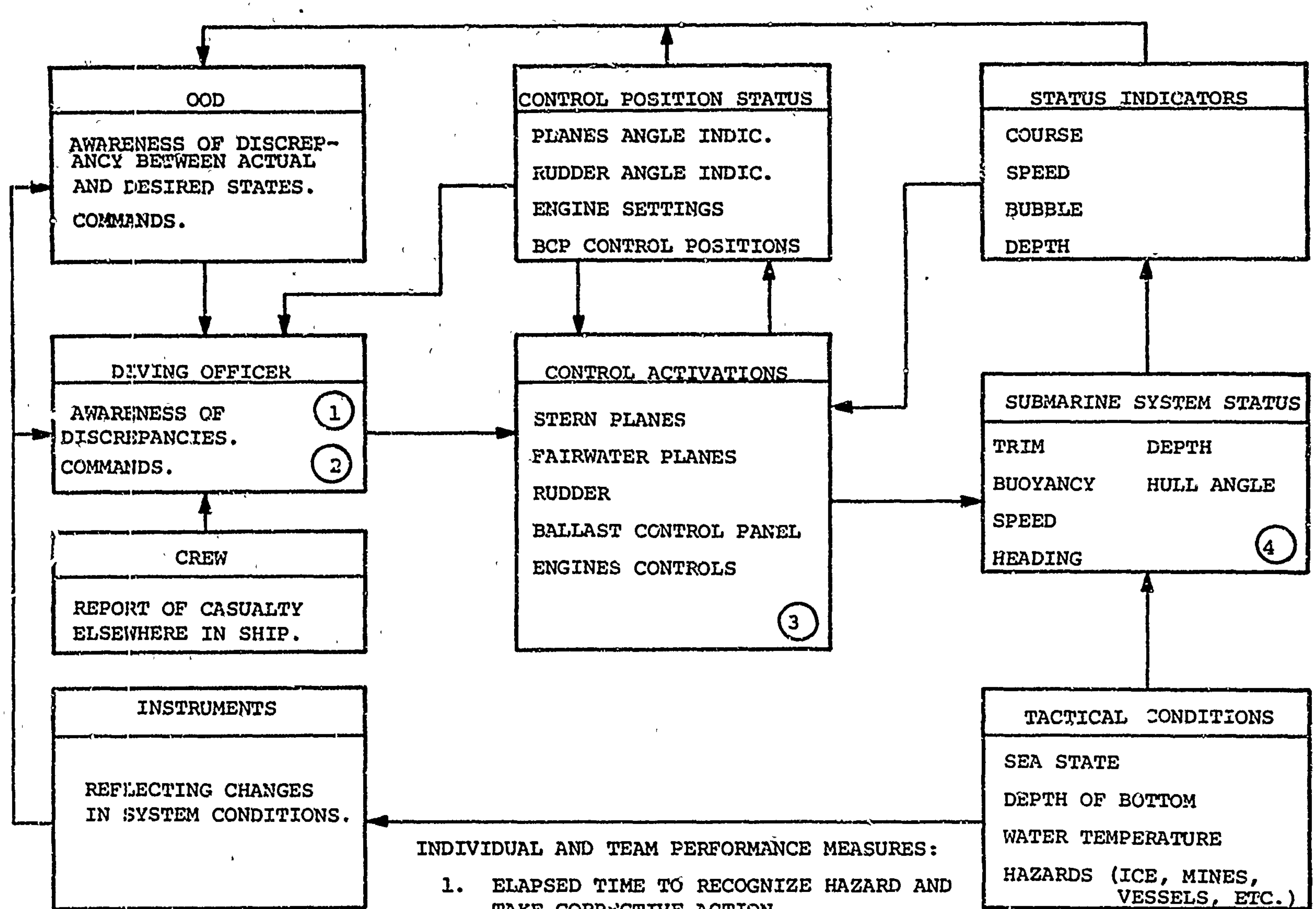
*Buoyancy and trim disequilibrium can be at least partially compensated for by changes in speed and planes angles. Considerably out-of-trim conditions make the planes control substantially more difficult.



INDIVIDUAL AND TEAM PERFORMANCE MEASURES:

1. ELAPSED TIME TO RECOGNIZE HAZARD AND TAKE CORRECTIVE ACTION.
2. APPROPRIATENESS OF COMMANDS, CLARITY OF COMMANDS (PHRASEOLOGY).
3. OPERATOR RESPONSIVENESS TO COMMANDS (TIME); CORRECTNESS OF RESPONSE (CONTROL POSITION)
4. EFFECTIVENESS OF COLLECTIVE EFFORTS OF TEAM (DEPTH, TIME)

Figure 1. Gross Events for Submarine Diving Team Relevant to Performance Criterion Selection.

D. STANDARD EXERCISES

Because of the difficulties inherent in measuring performance across tasks of changing complexity and attempting to derive indices of learning, the stratagem was selected of administering standard exercises each trainer session. The school and the instructors were extremely cooperative in this endeavor and allocated the first 15 minutes of each two-hour trainer session for the standard exercises.

The fundamental task confronting each crew was to maintain ordered depth while operating in trim at neutral buoyancy. This task is rendered somewhat more difficult during speed changes than at a constant speed; consequently after a "warm-up" period of 30 seconds at constant speed the OOD (played by the instructor) would order a speed change. After 90 seconds the OOD ordered a depth change and two minutes were allowed for the crew to reach ordered depth. The trainer was then "frozen" and the trial ended. Crew members then changed stations and the above trial was repeated, after which the students again changed crew stations. Commencing with the second trainer session a third trial was added. This also involved maintaining ordered depth but the instructor established a negatively buoyant condition at the start and advised the DO that he had speed control. The crew was permitted two and one-half minutes to recover from the sinking condition and stabilize at the ordered depth. This trial, which was suggested by one of the school instructors, involved skills which were beyond the capabilities of students in the first trainer session (speed control and BCP operation). Consequently, it was initiated at the second session and each session thereafter.

The specific conditions for the three trials were as follows:

Trial I:	buoyancy	-	neutral
	initial depth	-	130 feet
	initial speed	-	ahead 1/3
	ordered speed	-	ahead 2/3
	ordered depth	-	200 feet
Trial II:	buoyancy	-	neutral
	initial depth	-	200 feet
	initial speed	-	ahead 2/3
	ordered speed	-	ahead Standard
	ordered depth	-	130 feet
Trial III:	initial depth	-	130 feet
	initial speed	-	ahead 1/3
	buoyancy	-	20,000 lbs. heavy

Trial III: (cont.)	trim	-	all right fore and aft
	ordered depth	-	maintain 130 feet

As noted above, these trials were administered to each of the 16 student crews throughout the five-week training course. In addition, the three trials were administered to two instructor "crews", and to three experienced submarine crews performing on the trainer appropriate to their class of submarine. The performance of these five crews provided some of the standards against which student performance was assessed.

E. INSTRUMENTATION AND CALIBRATION

The trainers were calibrated daily by inserting initial setup conditions (submarine depth, speed, heading) at the instructor console and comparing instrument readings at the console with those at the crew stations, (and with the computer printout on the SS(N)613 trainer).

The SS(N)613 trainer digital computer had limited core memory and was able to store successive readings of depth, speed, hull angle, sternplane angle and fairwater plane angle only for one trial when the readings were stored in memory at five-second intervals. Consequently, after each trial when the crew was changing crew stations, the core memory was printed out on a highspeed Datamark line printer. These readings were also used for the daily calibration.

The SSB(N)627 trainer was, as has been noted, driven by an analog computer which had no provision for recording operator performance. An electric stylus, multi-channel Sanborn oscillographic recorder was, therefore, placed on the mezzanine adjacent to the trainer, and shielded cables were routed from the computer on the floor below. From his vantage point on the mezzanine the experimenter could monitor the trials, operate the recorder, and make appropriate notations on the record. The trainer and the recorder were calibrated daily by assuring pen sweep from limit to limit on the appropriate potentiometers and by cross-checking instrument readings at the instructor's console with those at the crew stations. The recorder was set to drive at a chart speed of one millimeter per second. Since the chart paper was graduated at five millimeter intervals, readings could be easily made at five second intervals to correspond with those obtained from the SS(N)613 trainer's high-speed printer.

F. TECHNIQUES OF MEASUREMENT

The combined actions of the diving team resulted in printouts at five-second intervals which indicated the simulated depth of the trainer. When these depth readings are transcribed in chart form they represent a continuously changing set of events which collectively illustrate the (vertical) track of the simulated submarine. The measurement task is to define aspects of this track which will be descriptive of the shape of the track and which will be relevant to some desired performance standard. For example, for the task of changing depth to 200 feet, a performance measurement might have been defined as the elapsed time from the command to change depth until the submarine achieved the ordered depth. Such a measurement point is unsuitable, however. It may not be descriptive of the shape of the track if the submarine is not stabilized at the ordered depth and it may therefore, yield values which are not relevant to a desired performance standard. If the crew undershoots the ordered depth the measured value will be infinity. If the crew rapidly establishes a steep dive

angle and overshoots the ordered depth, the measured value will be misleading as a description of crew performance. Moreover, the command to change depth was to be given at a particular time, not necessarily when a crew was at a given depth. Thus, if a crew was below the ordered depth of 130 feet when the command was given to change to 200 feet, it could conceivably achieve a 200 foot depth more readily than a more competent crew which had been maintaining the 130 foot depth precisely.

For many training devices a single point measure may be entirely appropriate as an index of performance, as in a simulated bomb drop, for example, when CEP can be calculated, or a simulated missile firing when a kill probability can be computed. For continuous tracking tasks such as in the present study such measures present an incomplete description of events. If several such measures are taken in order to describe the events more fully, there is a problem in meaningfully combining the measures into a single "score" which can be statistically manipulated.

In the present study the primary measurement technique involved describing the submarine's track in terms of its total deviation from ordered depth during each particular trial segment. On trial I, for example, absolute deviation scores from ordered depth were obtained every five seconds from the time of the command to increase speed until the command was given to change depth. Then, absolute deviation scores from the new ordered depth were obtained every five seconds until the trial ended. Similarly, during trial III, absolute deviations from ordered depth were obtained at five second intervals from start to end of the problem.

In addition to these "area under the curve" measures, a number of discrete measures were obtained. On trial III (the buoyancy problem) the maximum depth was noted, as well as the time at which it occurred. On the speed change problems, the relative changes in depth (porpoising) from one five second reading to the next were calculated. On both the speed change and the depth change problems the number of depth readings which were within two feet of ordered depth were tabulated. Finally, on the depth change problems the elapsed time was recorded from the time the order was given to change depth until the trainer achieved its maximum hull angle for the trial.

It will be noted that each of these measures is in accord with the intent to measure the resultant output of team actions. Consideration was given to the measurement of sternplane angles and fairwater plane angles but these measures reflect individual operator technique rather than team output.

SECTION IV

RESULTS

A. RELATIVE EFFECTIVENESS OF TRAINERS

The major study interest was in assessing the effectiveness of the SS(N) 613 attack submarine diving trainer in achieving training goals at the Submarine School. For the subject sample which was selected, this trainer was used in conjunction with the SSB(N)627 fleet ballistic missile submarine diving trainer. During their seven training sessions the students alternated between the two devices. Consequently, a comparison of student performance on the two devices during the five-week course became a matter of interest.

The crews had been assigned several tasks to perform during a standard exercise. These tasks varied in difficulty and are, therefore, considered separately in the following presentations. Figures 2 and 3 indicate student crew progress in maintaining ordered depth during a speed change of from 1/3 to 2/3 speed and from 2/3 to Standard speed, respectively. Performance on the SS(N)613 and SSB(N)627 trainers is indicated on each figure. In addition, the mean performance of experienced crews on each trainer is shown.

Figures 4 and 5 present similar data concerning accomplishment of the depth change task at 2/3 speed and at Standard speed, respectively. These data cover the final 60 seconds of the evolution.

Figure 6 indicates student crew performance in maintaining ordered depth under a condition of negative buoyancy.

Each figure indicates a fairly consistent decrease in depth deviation scores across training sessions as the students apparently improved their skills in maintaining depth control. However, a word of caution is expressed concerning additional interpretations. There is a noticeable consistent tendency for performance on the SS(N)613 to be less deviant than performance on the SSB(N)627 trainer. This cannot be interpreted as indicating that the one device is necessarily superior to the other. It will be noticed that mean performance levels of experienced crews also indicate "better" control in SS(N)613 trainer. Therefore, inter-trainer comparisons in terms of rates or amounts of learning, if such comparisons are made at all, should be made only after the two devices are equated in terms of difficulty to control.

B. RELATIVE RESPONSIVENESS OF TRAINERS

The relative responsiveness of the two trainers may be evaluated in terms of the time required to attain a maximum hull angle during depth changes. For the SS(N)613 this time was 25.6 seconds, averaged for both of the depth change trials performed by all teams in all seven training sessions. For the SSB(N)627 trainer the corresponding time was 34.1 seconds. Similarly, the time required to attain a maximum rate of depth change was 35.1 seconds and 51.5 seconds for the SS(N)613 and SSB(N)627 trainers, respectively. For both of these sets of measures, t tests of statistical significance yielded probabilities less than .01 that these were chance differences.

These differences in responsiveness to control actions influence the selection of methods to display the study findings. If the intent is to compare performance on the two trainers during each of the seven training

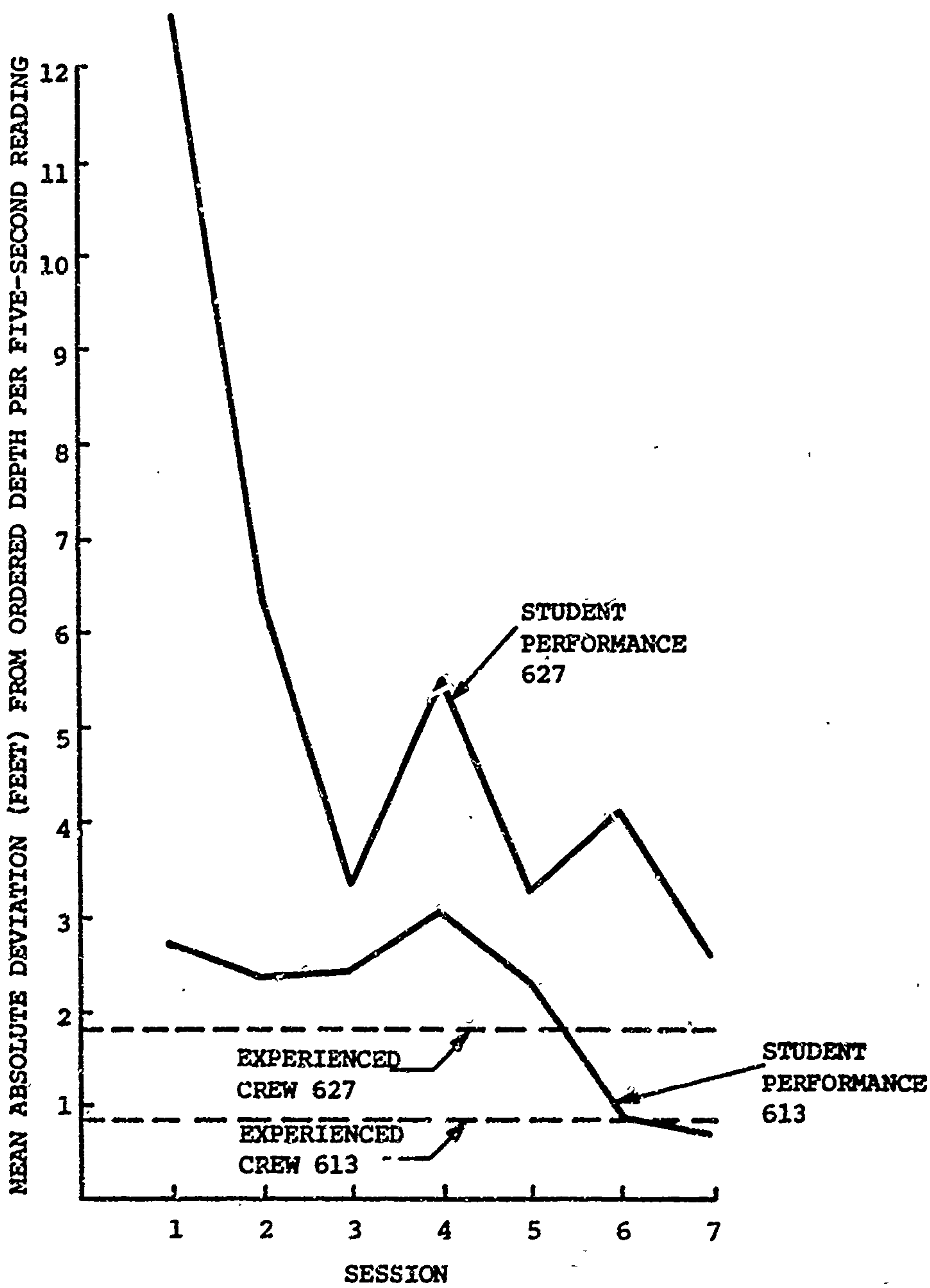


Figure 2. Comparison of Student Performance on the SSB(N) 627 and SS(N) 613 (21B20/A) Trainers:
Speed Change, 1/3 to 2/3, Trial I

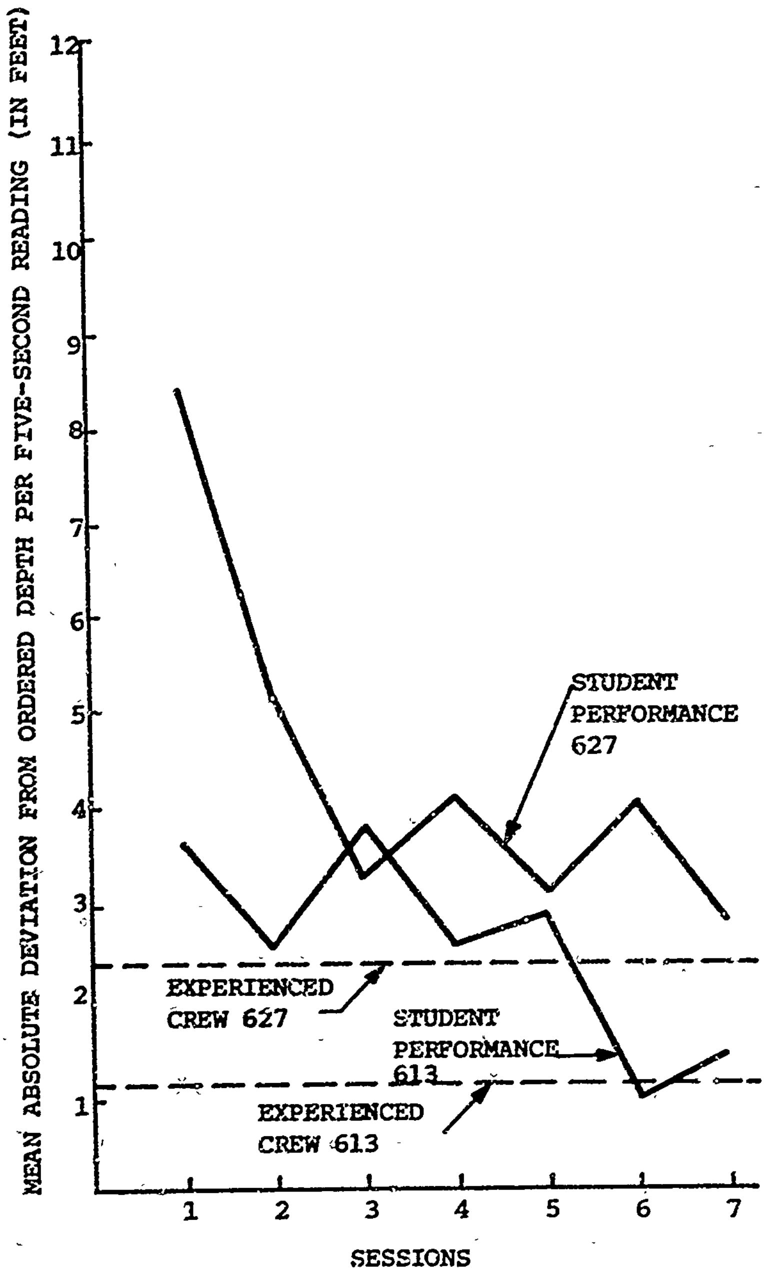


Figure 3. Comparison of Student Performance on the SSB(N) 627 and SS(N)613 (21B20/A) Trainers:
Speed Change, 2/3 to Standard, Trial II

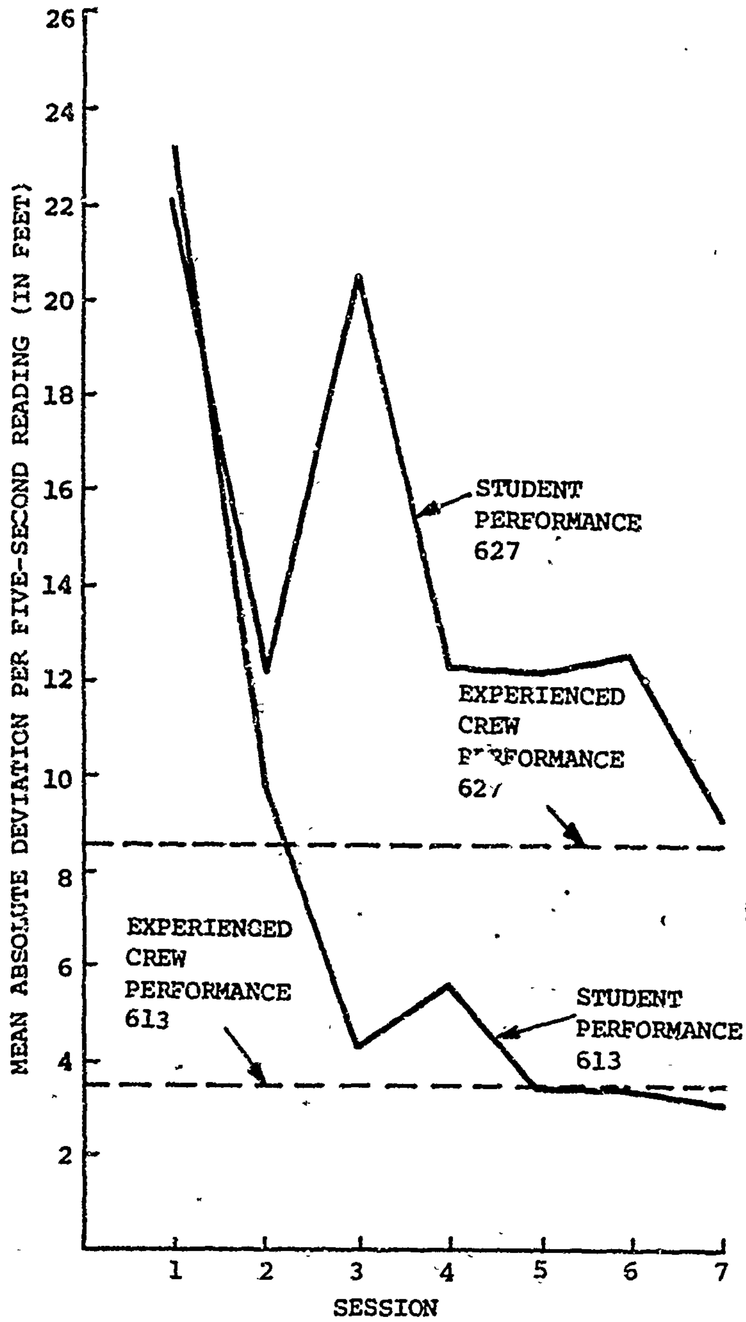


Figure 4. Comparison of Student Performance on the SSB(N) 627 and SS(N)613 (21B20/A) Trainers:
Depth Change, 130 to 200 Feet, Last 60 Seconds of Trial I, 2/3 speed

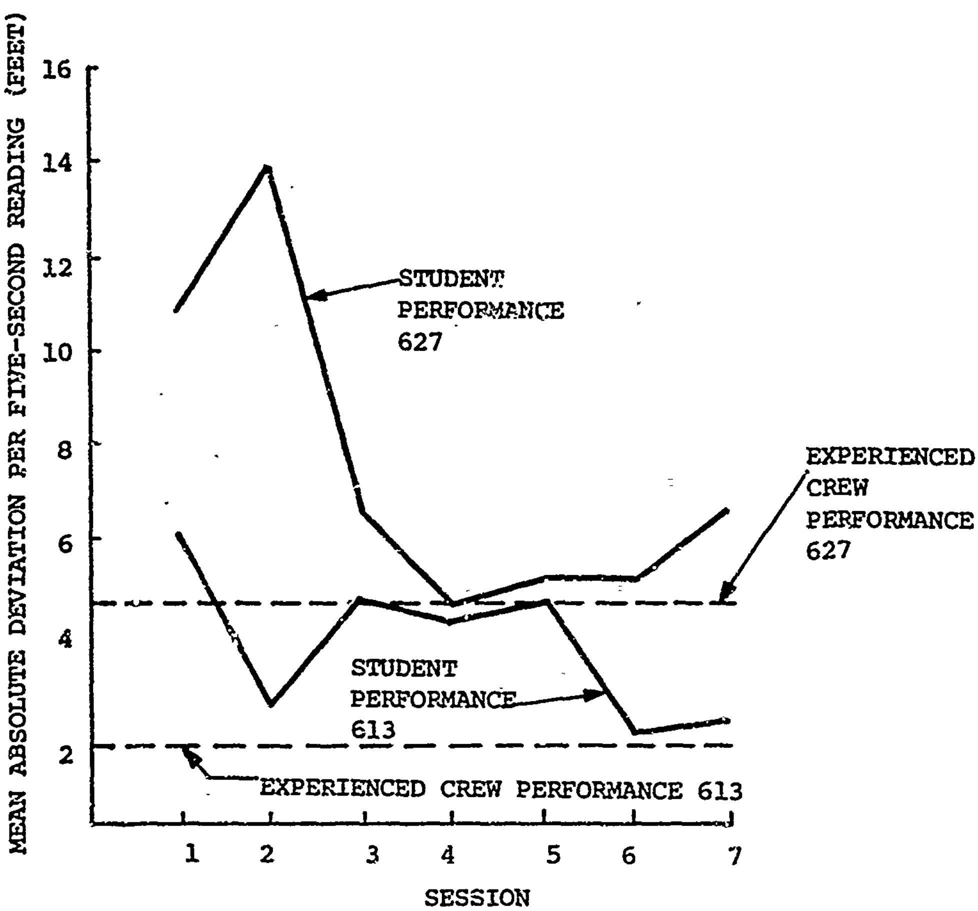


Figure 5. Comparison of Student Performance on the SSB(N)627 and SS(N)613 (21B20/A) Trainers: Depth Change, 200 to 130 Feet, Last 60 Seconds of Trial II, Standard Speed.

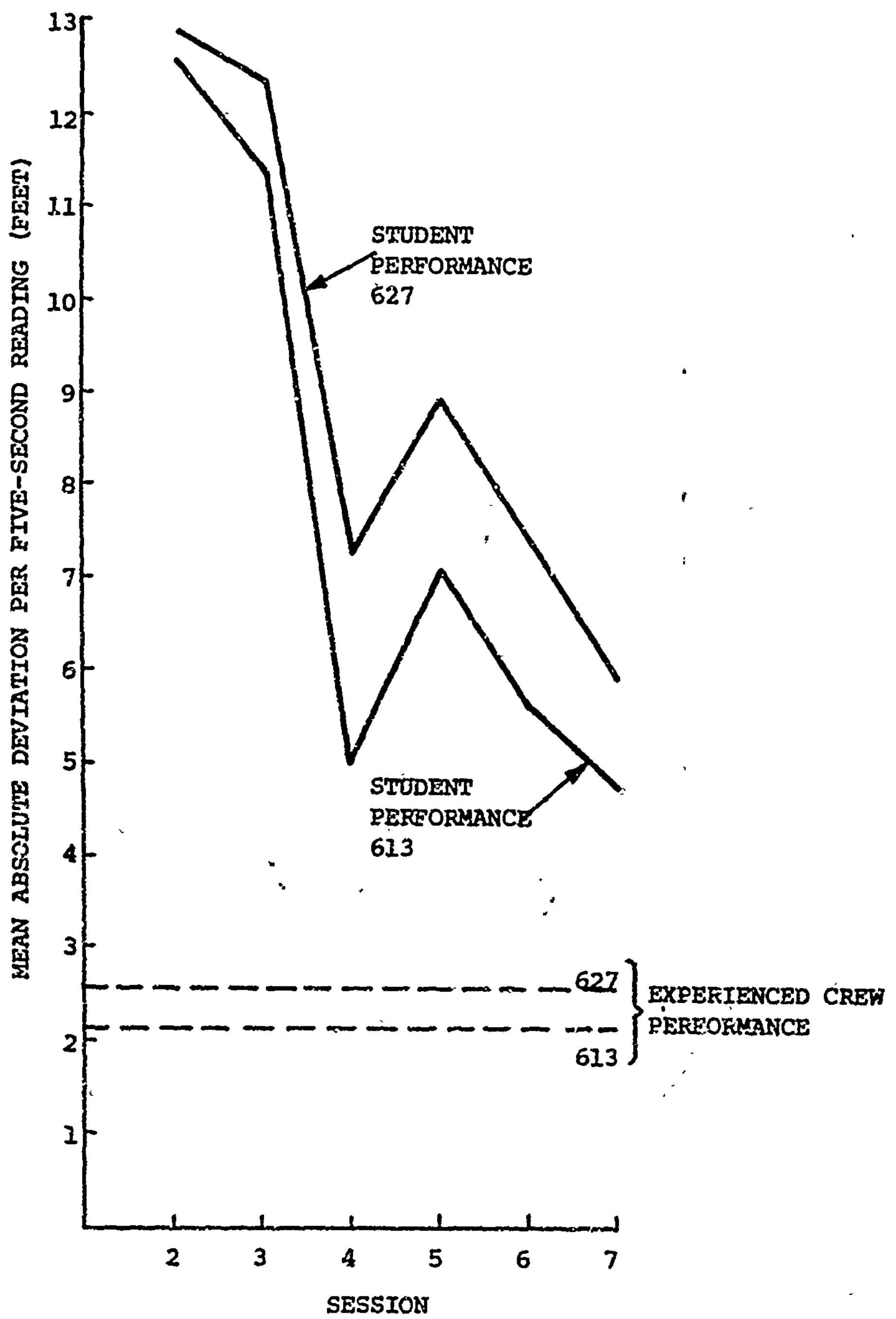


Figure 6. Comparison of Student Performance on the SSB(N)627 and SS(N)613 (21B20/A) Trainers:
Buoyancy Change -- Trial III

sessions then no transformation of data is necessary. If, however, the intent is to demonstrate whether performance of student crews improved over the training course duration then some adjustment must be made to equate the trainers in terms of their relative difficulty of control.

Equating the trainers can be managed by expressing student crew task performance on each trainer as percentages of the task performance scores achieved by experienced crews on that trainer. Plotting the transformed scores for each task and each training session will indicate relative rates of learning on the two trainers. Also, these transformed scores can be averaged for the two trainers on each training session to yield an overall "trainer learning curve".

C. RELATIVE DIFFICULTY OF TASKS

One indication of difficulty in performing a tracking task is the number of control reversals occurring per unit time. In the present instance there were several time periods which involved the maintaining of an ordered depth and which were not preceded by substantial control movements (as would occur, for example, in changing depth). Although the 30-second "warm-up" periods preceding the commands to change speed were not intended to be measurable tasks in this study, they do serve a useful purpose in indicating interactions between submarine trainer speed and maintaining depth. For these warm-up periods and during the tasks involving speed changes the absolute differences between successive depth readings were tabulated, and adjustments were made to equate the 30-second warm-up periods with the 90-second speed change periods. The results of these tabulations appear in Figure 7.

It should be noted that these measures of incremental depth changes are fundamentally different from other measures used in this study which concern deviations from ordered depth. A crew might, for example, be consistently ten feet above ordered depth during an entire task. The depth deviation score would reflect this error but a measure of incremental depth change would be zero.

The data in Figure 7 indicate a marked progression in task difficulty (tracking), as reflected by incremental depth changes, for the speed changes in the two trainers. The ordinate is expressed in index form to illustrate relative difficulty. Depth variability with an index of 100 was twice as great as that with an index of 50. The progression is similar for both trainers although the SSB(N)627 trainer is consistently more variable than is the SS(N)613 device. This is an interesting finding in view of the responsiveness data presented previously. Attention is also drawn to the scores of experienced crews during the speed change tasks. The SSB(N)627 experienced crews exhibit less depth variability than do crews experienced in the SS(N)613. The sample size is too small to attach significance to this finding but it may be worthy of note. One might expect that the much larger and heavier ballistic missile submarine would be more sluggish than an attack submarine and , therefore, would exhibit less porpoising in maintaining an ordered depth. This expectation is supported by the performance of the experienced crews on the speed change tasks (but not during "warm-ups") and is not supported by performance of the student crews on any of the tasks.

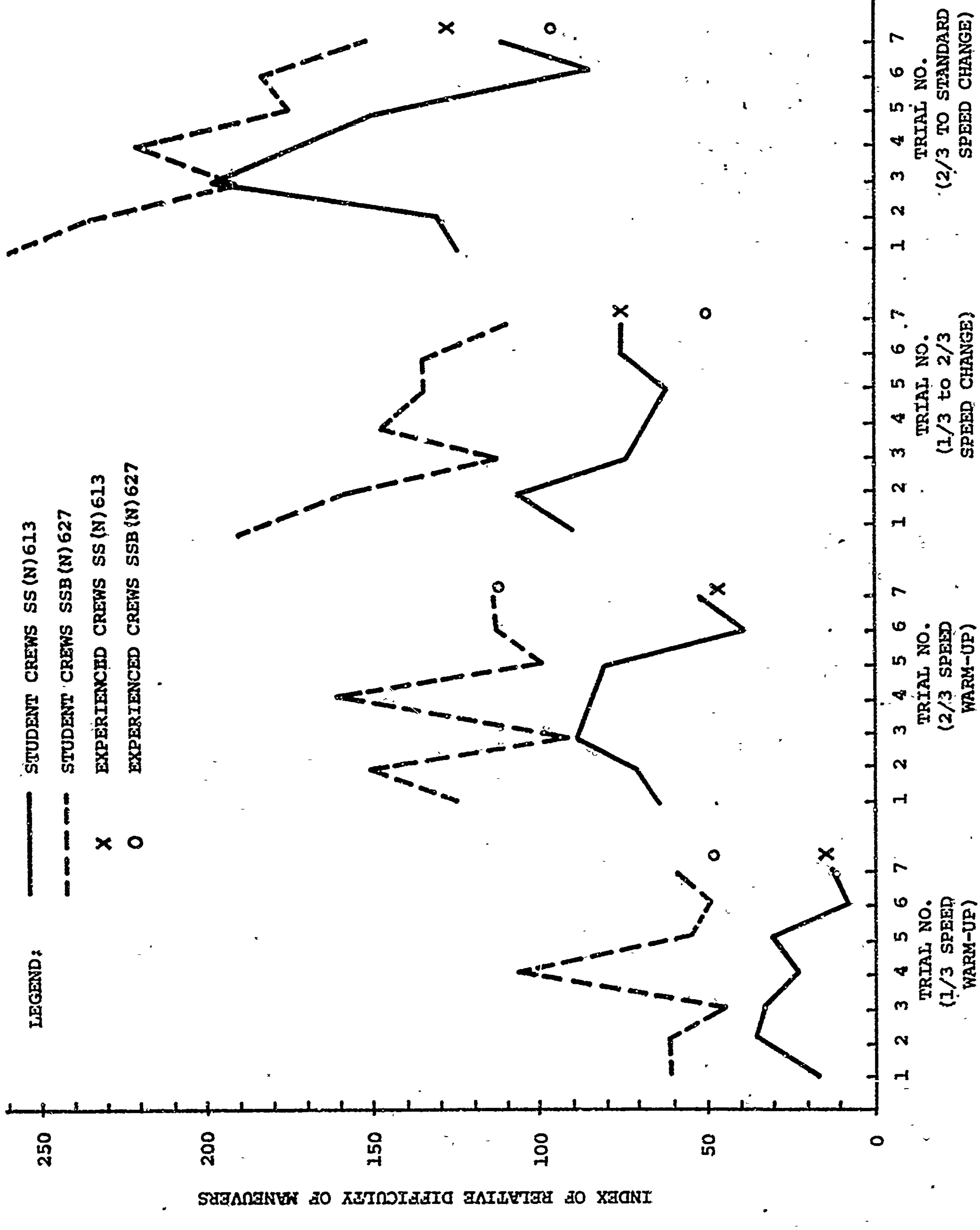


Figure 7. Incremental depth changes (porpoising) at five second intervals while attempting to maintain depth (data adjusted to equate task duration)

D. TRAINER CALIBRATION AND DRIFT

It has already been noted that trainers and recording devices were calibrated daily. Calibration was achieved in a number of dimensions but not with respect to speed. In view of the influence of speed upon difficulty in maintaining depth it may be illuminating to include results of an exploration made during initial stages of the study.

Recordings were made of engine revolutions per minute during periods of warm-up and speed change in the SS(N)613 trainer. On two successive sessions there was a 10% difference in rpm at initial setup for engine settings of 1/3 and 2/3. By the end of each of the two "warm-up" periods the rpm had increased by 8% and 3% even though engine settings were unchanged at 1/3, and rpm increased 13% and 6% during the 30-second "warm-up" periods at 2/3 speed settings.

When engine settings were changed from 1/3 to 2/3 and from 2/3 to Standard speed on two successive trials the rpm acceleration curves were highly similar for both trials. Standard speed was identical for the two trials despite a 7% difference at the start. In increasing from 1/3 to 2/3 speed there was a 3% discrepancy at termination of the trial.

These findings were discussed with instructor personnel at the Submarine School. It was the opinion of these experienced officers that the discrepancies would not affect study results since there were many other conditions which would also affect submarine speed (and, consequently, control). The major factor affecting speed would be planes angles, and the maximum discrepancies noted above would result in only a one-knot discrepancy.

This conclusion is accepted. However, in view of the preceding analyses indicating speed effects upon depth control it must be assumed that even a one-knot discrepancy will exert some influence. This trainer drift must, therefore, be considered as a contributor to error in the reported results.

No analyses similar to the above were conducted on the SSB(N)627 trainer. Available channels on the oscillograph were all assigned to variables of direct importance to the study.

E. EVIDENCE OF LEARNING

In view of the foregoing analysis, student crew performance scores (deviations from ordered depth) were considered as a percentage of experienced crew performance measures:

$$\frac{\text{Student Crew Score} - \text{Experienced Crew Score}}{\text{Experienced Crew Score}} \times 100$$

These scores were computed separately for the two trainers and for the three tasks explored during the study. Student crew scores were computed for each training session. The percentage scores were then averaged for each trainer. Results are presented in Figure 8. The results indicate that, whereas proficiency in attaining depth shows nearly a linear progression, the task of maintaining depth during speed changes conforms more closely to traditional

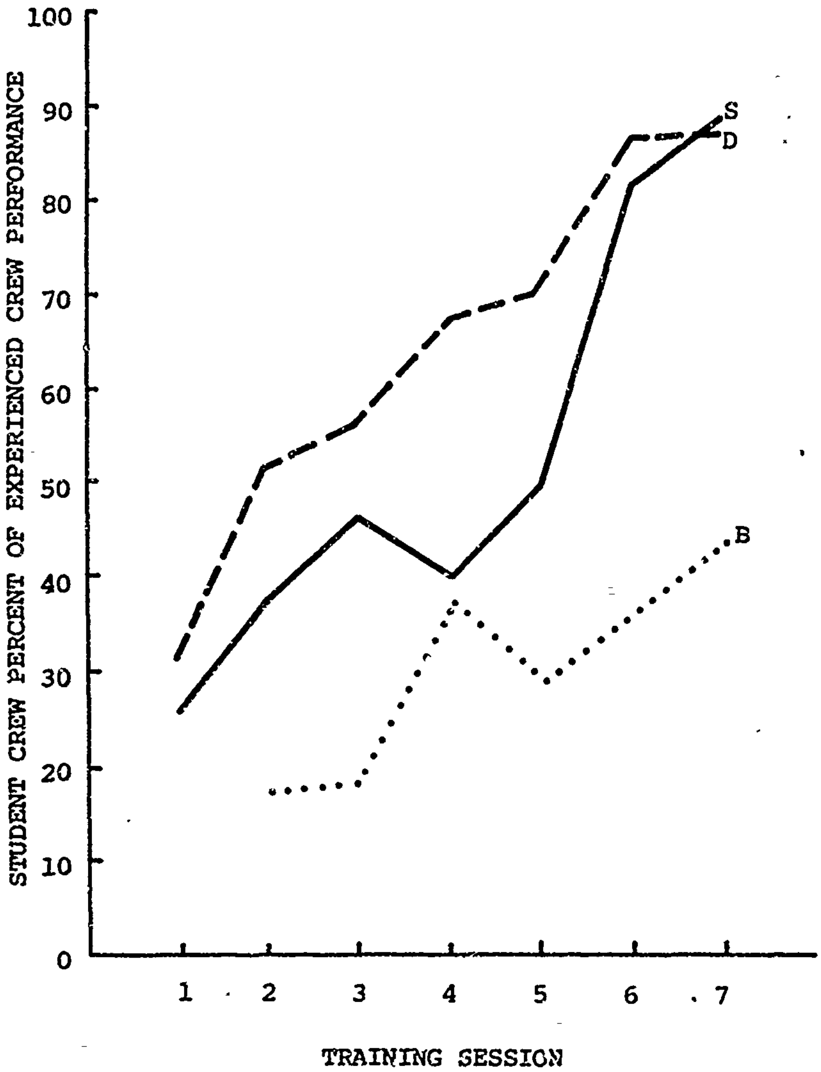


Figure 8. Student performance expressed as a percentage of experienced crew performance in: maintaining depth during speed changes (S), attaining ordered depth (D), and regaining ordered depth during buoyancy problem (B), on both trainers.

"learning curves", exhibiting a rise, a plateau, and a second rise. The buoyancy task, as expected, was difficult for the student crews. At the seventh session their performance remained far below the experienced crews' capabilities.

These same analyses are presented in Figure 9, but with the two trainers considered separately. Although the curves are somewhat more erratic than those in the previous figure, the same trends are observable.

F. EVIDENCE OF NEGATIVE TRANSFER

As mentioned previously, the SS(N)594 simulator was used for a brief period of training as a substitute for the SS(N)613 when the latter simulator was shut down for repairs. Of the eight student crews scheduled for the fourth training session on the SS(N)613, five had to be reassigned to the SS(N)594 device.

To determine if the introduction of the SS(N)594 training session had an effect upon crew training the crews' performances on training session 5 were compared with their performances on training session 3. The comparisons were made in terms of whether session 5 performance was "better" or "worse" than performance during session 3 on deviations from ordered depth for speed change, depth change and buoyancy tasks.

Of the three crews who received training session 4 on the SS(N)613 device, 13 scores* showed improvement and two scores were "worse" on session 5 than on session 3. Of the five crews who received training session 4 on the SS(N) 594 trainer, 11 scores showed improvement and 14 scores were "worse". A chi-square test of this distribution yielded a value of 7.11 which, for one degree of freedom, gives a probability of less than .01 that this result occurred by chance.

This result is particularly noteworthy when one considers that the standard exercises were routinely administered during the first 15 minutes of each training session. Thus, from the third to the fifth training session measurement points the crews received two lessons of one and three quarters hours each, only the second lesson of which was spent on the SS(N)594. Tests similar to the above were, therefore, made for other samples of lessons separated by alternate trainers. Results were uniformly negative (not significant). Interpolation of the SS(N)594 device had a negative effect upon learning. The extent of the measured effect is tempered by the fact that the positive influence of the other one and three quarter hour sessions cannot be partialled out.

The negative effect was temporary. Analyses similar to the above were performed for crew scores on the sixth and seventh training sessions. The sixth session analyses yielded a Chi-square value of 5.23 which, for one degree of freedom, is significant at the .05 level. However, the seventh session analyses indicated no significant differences between the groups. The deficit incurred in session four had been overcome in the two subsequent training sessions.

* The five scores for each crew used in this analysis were: mean absolute deviation from ordered depth during two speed changes and two depth changes and the mean absolute depth deviation during the buoyancy problem.

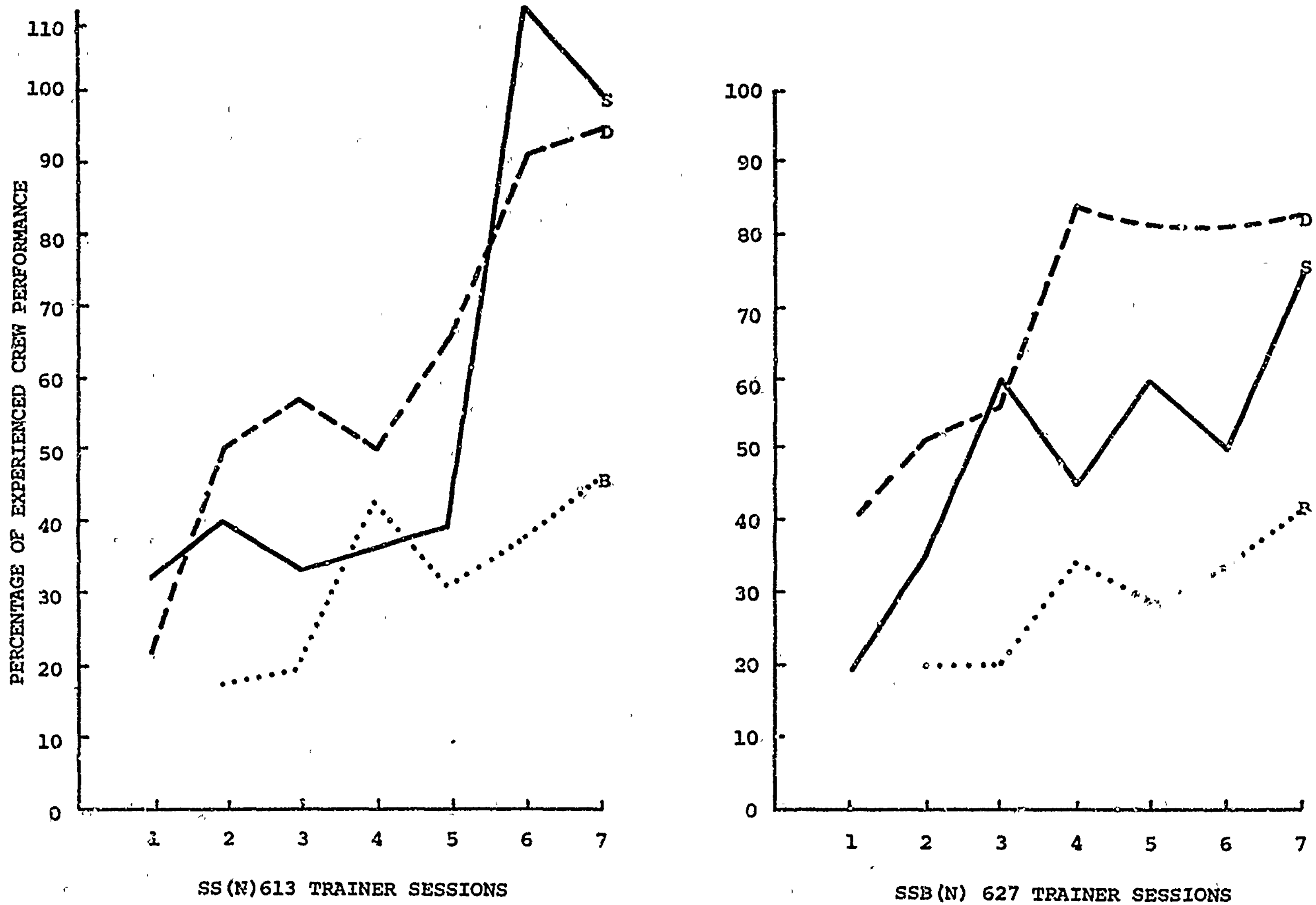


Figure 9. Student performance expressed as a percentage of experienced crew performance in: maintaining depth during speed changes (s), attaining ordered depth (D), and regaining ordered depth during buoyancy problem (B) with trainers separately considered.

SECTION V

DISCUSSION

The present study had a dual orientation: that of considering problems inherent in evaluating trainer effectiveness within the context of a training setting, and evaluating a specific submarine diving trainer for its training effectiveness.

The study included an analysis of major variables to be considered for post hoc, statistical control in analyzing study findings, since research in a training environment often precludes experimental manipulation of these variables. Of particular relevance in this regard are the Figures 2 through 6 which present results of student performance on the SS(N)613 and SSB(N)627 trainers. The relative responsiveness of these two devices (which apparently duplicate sea performance of their respective submarines) are substantially different. Therefore, care must be taken in making direct comparisons between the two devices. The study indicates how graphs of performance improvement change when student crew performance on each device is related to a standard appropriate to that device (see Figure 9). In this case, the standard was experienced crew performance on the devices. In other studies it may be possible to obtain performance measures in the operational setting.

A related point worthy of note concerns the results presented in Figure 9. This illustration indicates student performance improvement on individual trainers relative to a performance standard appropriate to each trainer. There is a marked similarity between the respective curves of performance improvement for the buoyancy problem. The performance curves for the speed change and depth change tasks show a similar steep rise although performance on the SSB(N)627 does not quite attain the same high levels shown for the other device.

These curves are remarkable more for their similarity than for the slight differences they show. The sawtooth nature of some of the curves is probably attributable to small sample effects. The two trainers are slightly different in their display layouts but substantially different in terms of control feel and device responsiveness. Yet learning progress for students alternating between the trainers exhibits essentially similar improvement on each device. It will be recalled that samples were taken to analyze performance improvement or decrement on the same trainer as a consequence of interpolated training on the alternate device. That is, scores for sessions 1, 3, 5 and 7 on the SS(N)613 were examined to note whether consistent changes occurred which could be attributed to the interpolated SSB(N)627 training during sessions 2, 4, and 6. Similar analyses were made for SSB(N)627 trainer sessions when the SS(N)613 trainer was interpolated. Except for the condition when the SS(N)594 trainer was interpolated, these analyses indicated no statistically significant differences. The SS(N)613 and SSB(N)627 trainers differ in their display configurations and in their responsiveness to control activations. Yet interpolated practice on either of these trainers does not impede improved performance on the alternate device. One might conclude, therefore, that variations in control/display relationships of the magnitude encountered here exert negligible effects upon trainer effectiveness.

In brief, these findings support the practice at the Submar.ne School of alternating training sessions on these two types of diving trainers.

On the other hand, the results of analyzing influences of the SS(N)594 trainer strongly suggest that use of this trainer as a substitute may tend to impede student progress. As a consequence of the discovery of indications of negative transfer effects, tabulations were made of characteristics of the SS(N)594 device which could possibly have contributed to the findings. There is no way of ascertaining which of these features (or if any of these) was significant during the study. However, it appears reasonable to assume that the observed negative training effects might be attributable to trainer differences with respect to displays, control "feel", or trainer responsiveness. In these general categories, the ways in which the SS(N)594 device differed from the other two trainers were noted.

On the subject trainer, the only display of the ship's trim angle appears on one instrument on the combined instrument panel. This display is located some 40" from the operator. The scale is non-linear and, near the zero-angle position, the degree graduation marks are at 1/4" intervals. The instrument is not an easy one to read. This display appears on the other trainers also, but redundancy is provided by a mechanical "bubble" which actually serves as a primary reference for the planes operator.

On the SS(N)594 device there is no emergency indicator on the planes angle display and there is no shallow depth gauge. The deep depth indicator is graduated at 100 foot intervals and, in the 130-200 foot range used in this study, would provide inadequate information for precise depth control. The students would in this event rely upon a depth error indicator, an instrument with which they are relatively unfamiliar.

With respect to control design, there is no tension adjustment control on the SS(N)594 device and no emergency power on the planes. The absence of a tension adjustment control is reported by the instructors as being particularly unrealistic and introduces an unnatural "feel" to the planes and rudder controls.

Finally, several measures were made relative to trainer responsiveness at 2/3 and at Standard speeds. The times required to attain a 5° hull angle at these speeds ranged from seven to ten seconds, substantially faster than the 25.6 required on the SS(N)613 device or the 34.1 seconds required on the SSB(N)627. These measures were compared with sea trial data* and were found to be quite similar to responsiveness measures on the actual submarine.

It may not be unreasonable to suggest that a combination of such substantial differences in control "feel" and trainer responsiveness during the fourth trial performed on the SS(N)594 device could explain the poorer performance of students during the first 15 minutes of the fifth trial performed on the SS(N)613 trainer. Such inter-trainer differences are apparently greater in their effects than the differences noted previously for the SS(N)613 and SSB(N)627 devices which had no measurable negative influence upon training progress.

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* Ruscus, P.Y. USS Permit (SSN594) emergency recovery tests. Washington, D.C.: Naval Ship Research and Development Center, Hydromechanics Laboratory Test and Evaluation Report, July 1967. (Title Unclassified, Report Confidential)

With respect to evaluating the SS(N)613 and SSB(N)627 devices for their training effectiveness, it is evident that incomplete results were obtained. As noted in an earlier section of this report, study conditions did not permit the inclusion of submarine-qualified crews as study subjects. Consequently, important capabilities for casualty training which are potentially available in the two training devices could not be assessed. A partial listing of these capabilities appears in Appendix C. The reader will note, by comparing this listing with the SOIC training course contents present in Appendices A and B that relatively few of the trainer design capabilities can be suitably exercised during the short duration of the SOIC training program.

One might, therefore, consider the issue of trainer evaluation within the larger context of trainer utilization.

As employed in the SOIC training program, the use of the SS(N)613 and SSB (N)627 devices resulted in student performance, by the seventh session, which closely approximated experienced crew performance in routine depth control. Student performance in coping six times with the same relatively minor ship control problem of negative buoyancy improved but slightly, and did not approach levels achieved by experienced crews who performed the task only once. One might suspect, therefore, that student performance on still more difficult evolutions (e.g., "Emergency Deep") and on compound casualties would be grossly deficient after a course of such brief duration. This would be acknowledged by the school since the SOIC curriculum is limited to demonstrations of compound casualties and the SOIC students are not expected to achieve competence in such advanced manuevers. What, therefore, is the rationale for incorporating diving simulators in the indoctrination course?

The stated intent of the course to train the student to perform the duties of diving officer on a submarine. Interviews with operational submarine personnel indicated that no recent graduate would be trusted at a diving officer station without extensive OJT and additional simulator training. This is a firm requirement regardless of how effective the "academic" training may be. (Appendix D presents one submarine's procedure for qualifying a diving officer.) The estimated duration for qualifying was expressed as varying from three to six months, depending upon other duties assigned to the officer and upon his degree of improvement in performance. At best, therefore, during the SOIC course, the diving trainers serve to familiarize a student with some diving officer duties, to acquaint him with planes and BCP operator stations (which he will rarely man under normal conditions), and to provide practice in phraseology and giving commands.

With respect to the general question of cost and effectiveness of the devices the study did not achieve desired results. That students can indeed learn on the devices and that their levels of performance can approach levels achieved by experienced crews, was established. Since the full range of trainer capabilities could not be studied, it must as yet be only assumed that similar training improvements take place in more advanced training courses. If this is true (and it appears to be a reasonable assumption provided that the training course is suitably long) then the effectiveness of the devices is established, and the cost of the trainer can undoubtedly be justified on the basis of possibly preventing the loss of a boat.

The important point is that the cost of the entire device, including its capabilities to simulate a wide range of malfunctions, not be evaluated in terms of the effectiveness of the device in a training course of limited scope. Whether the devices are truly cost/effective in promoting training in coping with emergency conditions is as yet unestablished. That they are effective in the SOIC course is evident, but their effectiveness is not totally apparent to later job assignments.

SECTION VI

CONCLUSIONS

In view of the foregoing study results and analyses it is concluded that:

- The SS(N)613 and SSB(N)627 submarine diving trainers as used at the U.S. Navy Submarine School in the Submarine Officer Indoctrination Course result in demonstrable training improvements in performing basic maneuvers.
- The use of the SS(N)594 submarine diving trainer apparently was detrimental to student learning in the SOIC training context, and its use as a substitute trainer cannot be recommended at this time.
- The SSB(N)627 trainer, reflecting response characteristics of the fleet ballistic missile submarine, appeared to be slightly more difficult for the students to control than the SSB(N)613 attack submarine trainer. Students did not achieve quite the same level of performance on the SSB(N)627 device as on the SS(N)613.
- Despite marked responsiveness differences between the two trainers no negative influences were observable as a consequence of alternating training sessions on the two devices. However, there was some indication that the more substantial responsiveness of the SS(N)594 trainer exerted negative influences upon subsequent student performance on the SS(N)613 trainer.
- The negative influences of the one session on the SS(N)594 device were ameliorated by the two subsequent training sessions. Scores of the affected student crews were significantly lower on session six than were the scores of student crews who had not been assigned to the SS(N)594 trainer. However, the differences were eliminated by the start of the seventh training session.
- The trainers were designed to provide advanced casualty control training. However, these features were not evaluated in the present study which limited trainer assessment to basic ship control training. Conclusions concerning trainer effectiveness in promoting casualty control training are not possible at this time.

SECTION VII

RECOMMENDATIONS

Although the foregoing material questions the effectiveness of simulator training in the SOIC program, it is not recommended that such simulator training be eliminated from the course. Its inclusion does not appear to fulfill the stated goals of the course, an observation which is appropriate to the purpose of this study. However, if the goals of the SOIC program were modified to be consistent with operational requirements, the continued use of the trainers might be more justifiable. In this event, it is recommended that the possibility be explored of restructuring the course to place more emphasis upon issues directly germane to the diving officer's primary duties.

It appears that a substantial portion of the course is required to attain even modest levels of proficiency in controlling the submarine, duties which these SOIC students will rarely perform. Presumably the student officers are grouped so that those operating the planes controls and the BCP can benefit from instruction being given to the particular student acting as diving officer. It is possible, however, that their attention is so occupied in learning to control their particular station of the moment that they benefit relatively little from observations of others' performances.

It is considered desirable that the student diving officer "get formal exposure and exercise at the specific function of each member of the ship control team." The difficulty here apparently centers upon the degree of such cross-training which is desirable. It is recognized that it is desirable for the diving officer to be familiar with the job requirements of his subordinates and what difficulties they may experience in controlling the submarine. Such awareness will help him in avoiding giving commands which are unreasonable in certain circumstances. However, since the SOIC course duration is brief and this study's evidence suggests that only modest levels of trainee proficiency are achieved at the ship control stations it would appear that untoward emphasis is being placed upon developing manual skills which have limited applicability to later job assignments. This situation parallels a caution aptly expressed by Smode (1963)* "Effective use of a simulator requires extended periods of practice by trainees, else the device becomes no more than a demonstrator. Expensive demonstrators are luxuries that few training programs can afford."

It is suggested that more efficient use may be made of the trainer capabilities by placing more emphasis upon diving officer duties during diving officer training. This may possibly be accomplished by merging training of the potential diving officers with training being provided to the enlisted personnel who will eventually man the control stations. That is, after the student officers had attained a moderate level of proficiency in planes control (say, by the beginning of the sixth trainer session - see Figure 8) the following

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*Smode, A.F., Gruber, A., and Ely, J.H. Human Factors Technology in the Design of Simulators for Operator Training. Technical Reports NAVTRADEVCEN 1103-1, 1963, U.S. Naval Training Device Center, Port Washington, New York. (p. 118)

trainer hours might be conducted with combined officer/enlisted groups, emphasizing trimming and basic evolutions. SOIC students could alternate in assuming the role of diving officer. During the lessons, control station trainees would receive practice (and instruction) relevant to their future jobs and the remaining SOIC students could devote more of their attention to observing one of their group perform as diving officer. This would not obviate their observations of crew duties in the ship control area.

APPENDIX A

OBJECTIVES OF SOIC LECTURE SESSIONS

SESSION I: Introduction to Submerged Operations

OBJECTIVES: When the student completes this lesson he will be able to:

1. Describe the forces acting on a submerged submarine.
2. Describe the proper techniques for depth keeping and depth changing.
3. List the members of the ship control party and describe their depth control duties.

SESSION II: Trim Analysis I

OBJECTIVES: When the student completes this lesson he will be able to:

1. Describe the hydrostatic and hydrodynamic forces acting on a submerged submarine.
2. Describe the aids used for depth control.
3. List the requirements for a "Trim Satisfactory" report.
4. Explain how to recognize and correct trim for the considerably out of trim condition.

SESSION III: Trim Analysis II

OBJECTIVES: When the student completes this lesson he will be able to:

1. Explain how to recognize and correct trim for the "close in" trim condition.
2. Explain the interaction between the stern planes and sail planes.
3. Explain the effect of rudder on depth control.
4. Explain stern plane reversal effect (chinese planes).
5. Explain how to use the sound velocity profile (SVP).

SESSION IV: Special Evolutions

OBJECTIVES: When the student completes this lesson he will be able to:

1. Describe the sequence of operations involved in submerging a submarine.
2. List the requirements for reporting "Trim Satisfactory".
3. Describe the considerations relevant to making an ascent to periscope depth.
4. Describe how a submarine makes an ascent to periscope depth.
5. Know the orders given and the actions taken to perform the "Emergency Deep" procedures.

6. Describe the sequence of operations involved in surfacing a submarine.
7. Describe the sequence of actions involved in commencing and securing snorkeling.
8. Describe the sequence of actions involved in commencing and securing ventilation with the L.P. blower.
9. Describe the sequence of actions involved in preparation for hovering and during automatic mode of hovering.

APPENDIX B

OBJECTIVES OF SOIC TRAINER SESSIONS

SESSION I: Basic Depth Control

OBJECTIVES: When the student completes this lesson he will be able to:

1. Perform the basic functions of the inboard station and outboard station planesmen.
2. As Diving Officer maintain ordered depth.
3. As Diving Officer change ordered depth using proper procedures.
4. Recognize, report, and take proper corrective action for loss of normal indication and loss of normal power casualties.

SESSION II: Trimming I

OBJECTIVES: When the student completes this lesson he will be able to:

1. Recognize and correct significant out of trim conditions.
2. Maintain ordered depth by proper use of planes, angle, and speed while correcting out of trim conditions.
3. Properly report "Trim Satisfactory" after meeting all requirements.

SESSION III: Trimming II

OBJECTIVES: When the student completes this lesson he will be able to:

1. Meet the objectives of previous session.
2. Recognize and correct close in trim conditions.

SESSION IV: Trimming III

OBJECTIVES: When the student completes this lesson he will be able to:

1. Meet the objectives of previous session.

SESSION V: Diving, Surfacing, Trimming

OBJECTIVES: When the student completes this lesson he will be able to:

1. Submerge the ship, correct the trim and report "Trim satisfactory".
2. Ascend from 130 feet to periscope depth.
3. Surface the ship.
4. Execute "Emergency Deep".

SESSION VI: Special Evolutions Demonstration

OBJECTIVES: When the student completes this lesson he will be able to:

1. Prepare to snorkel (Diesel Engines).
2. Commence snorkeling.
3. Secure snorkeling.
4. Prepare to snorkel ventilate (L.P. blower).
5. Commence ventilation.
6. Secure ventilation.
7. Hover.

SESSION VII: Recoverability Demonstration

OBJECTIVES: At the completion of this lesson the student will have observed:

1. The effect of the major variables as they relate to severity of flooding and control surface casualties.
2. The proper casualty procedures for recovery from flooding and control surface casualties.
3. The results of improper casualty procedures for flooding and control surface casualties.

APPENDIX C

TRAINER CAPABILITIES FOR CASUALTY TRAINING
(Partial Listing)

Minor Casualties:

Fail speed indicator
Fail course sensor
Fail depth sensor
Fail stern plane amplifier
Fail fairwater plane amplifier
Fail rudder amplifier
Fail aux 1 and aux 2 levels
Fail ac power

Out-of-trim conditions
Buoyancy problems

Major Casualties:

Flooding under combinations of the following variables: speed, depth, flooding rate, flooding duration, time of detection (reported/unreported).

Planes casualty under combinations of: depth, speed, rudder fail and/or stern plane fail and/or fairwater plane fail under conditions of rise or dive.

Compound casualties: propulsion loss, reactor scram, hydraulic loss, with or without conditions of flooding and/or stern plane jam.

APPENDIX D

USS BERGALL (SSN667)
DIVING OFFICER OF THE WATCH QUALIFICATION CARD

Name:_______________________ Rank/Rate_______________

I **Prerequisites:**

A. Be a commissioned officer or

B. Be a petty officer qualified as Chief of the Watch

II **Knowledge Requirements:**

A. Demonstrate a thorough knowledge of the following systems to include general design criteria, interrelations with other systems, safety precautions and modes of operation: (Systems are to be signed off by cognizant division officer or a qualified diving officer of the watch. Repeat signatures are not required for previously qualified COW's; however, knowledge of all systems will be examined by the Ship's Diving Officer - item 19. below).

	Examiner	Date
1. Hydraulic Power Plant		
2. Main and Vital Hydraulics		
3. Steering and Diving Hydraulics		
4. External Hydraulics		
5. Flood Control		
6. High Pressure Air		
7. Service Air		
8. MBT Blow (Normal, Emergency & LP) and Vent		
9. Tanks and Compartments		
10. Trim and Drain		
11. Hovering and Depth Control		
12. Ventilation		
13. TDU		
14. Snorkel		

	Examiner	Date
15. Ship's Control Panel and Conalog	____________	____________
16. Ballast Control Panel	____________	____________
17. Basic Electrical	____________	____________
18. Main and Emergency Propulsion	____________	____________
19. For previously qualified COW's:		
knowledge of all of the above systems	____________ Ship's Div.Off.	____________

B. Demonstrate a thorough knowledge and be able to discuss the following topics as related to diving, surfacing and submerged ship control:

1. All planes casualties and proper corrective action.

2. Steering casualties and use of the rudder in casualty or normal situations.

3. Effects on trim and depth control of:

   a. Water temperature change.
   b. Sea state and wave effect.
   c. Hull compressibility.
   d. Ship aspect.
   e. Use of rudder.

4. Reserve Buoyancy.

5. Snorkel Safety Circuits.

6. Critical Electrical Power Supplies.

7. Hovering System operation in all modes.

8. Methods of compensating for weight changes.

9. Location and capacity of all major tanks.

10. Ratings of the Trim and Drain pumps.

11. Deballasting rates.

12. Effects of loss of 1S, 2S, 5S, 6S and 400 cycle switchboards.

13. Location of turning pivot point and centers of buoyancy and gravity.

14. Submerged and surfaced stability.

____________________ ____________
Ship's Diving Officer

C. Demonstrate a thorough knowledge of the ship's Deep Submergence Bill and recovery capabilities from a flooding casualty considering the following factors:

1. Initial air bank pressure.
2. Location of flooding.
3. Hole size.
4. Time to initiate blow.
5. Time to secure flooding.
6. Speed
7. Depth
8. Flooding recovery curves for this class.

______________________ __________
(DCA)

III Practical Work:

A. If unqualified in submarines, complete the DOOW portion of the Submarine Officer's Qualification Notebook.

______________________ __________
(XO)

B. Complete the following practical factors under the supervision of the officer indicated:

1. Rig all compartments and topside for dive.

Bow	______________________ (Duty Officer)	__________ Date
UL OPS	______________________	__________
ML OPS	______________________	__________
LL OPS	______________________	__________
AMR 1	______________________	__________
TUNNEL	______________________	__________
AMR 2	______________________	__________

ENG RM	(Duty Officer)	Date
TOPSIDE		

2. Demonstrate proficiency at the following stations:

BCP	(Diving Officer)	
Stern Planes	(Diving Officer)	
Fairwater Planes	(Diving Officer)	

3. Act as Diving Officer during casualty drills submerged to include:

Fire	(Diving Officer)	
Flooding	(Diving Officer)	
Stern Plane Jam	(Diving Officer)	

4. Dive the ship as Diving Officer (2)	(Diving Off.)	
5. Compute compensation after an inport period and act as Diving Officer for the initial dive.	(Diving Off.)	
6. Surface the ship as Diving Officer (2)	(Diving Off.)	
	(Diving Off.)	
7. Perform snorkel evolutions in all modes	(Diving Off.)	
	(Diving Off.)	
8. Perform hovering evolutions in all modes	(Diving Off.)	

9. Operate in all modes of course and depth control including single plane operation. ____________ ________
(Diving Off.)

10. Perform periscope depth operations (3) ____________ ________
(Diving Off.)

____________ ________
(Diving Off.)

____________ ________
(Diving Off.)

11. Stand a minimum of four watches as Diving Officer under instruction. ____________ ________
(Diving Off.)

____________ ________
(Diving Off.)

____________ ________
(Diving Off.)

____________ ________
(Diving Off.)

IV <u>Examination/Qualification:</u>

A. Pass a written and/or oral examination administered by the Ship's Diving Officer on all of the above subjects.

____________________ ________
Ship's Diving Officer Date

B. Examined and recommended for qualification as Diving Officer.

____________________ ________
Executive Officer Date

C. Examined and designated a qualified Diving Officer.

1. Provisional ____________________ ________

2. Final ____________________ ________
Commanding Officer Date